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Study on the layer spalling of the KMPS546 speed reducer input conical

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Abstract

In this paper, the spalling of the gear teeth surface was studied. It was concluded that there did not exist any contact fatigue dehiscence in the gear through macroscopic analysis, microstructure analysis and morphology of incision analysis. The main reason of the dehiscence spalling in the gear teeth was the presentation of fissuary. The fissuraing expanded and developed under the alternating stress to the gear teeth surface layer spalling. The formation and enlargement of the fissuary had a strong relation with its treatment process.

Keywords: surface layer, gear tooth spalling, fissuaring formation

1. Introduction

In the maintenance of conical shaped gear surfaces of KMPS546 speed reducer, surface layer spalling was found at three places. In order to find out the reasons for the surface spalling and prevent similar failures, the gear tooth with the most serious injury (the largest and deepest spalling area) was selected as the sample for analysis.

2. Macroscopic analysis

The largest spalling was shown in figure 1. The length and width of spalling area were about 5.5 mm and 4 mm, respectively. The spalling area could be divided into two parts, which were shown in the A-A line of figure 1. After removing the gear tooth by longitude line cutting and washing, a clear macro-crack could be found inside the gear tooth. The crack was long and thin and it also contained curves. The crack almost spread through the whole thickness of the gear tooth.

The whole spalling area could be divided into two portions. The place near the center shown in the oval region in figure 1, was the crushing and abrasing fatigue area. The places on both sides of the oval region were the rapid

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tearing area. It was easily found from this region that there were many barbs and shear lips formed by tearing nearby the peripheral part. It's generally concluded that the surface layer spalling was formed along the A-A line at the beginning, and then the spalling region extended to both sides of whole ellipse. In each meshing process, the dehiscence region confronted extrusion and wearing once again, and the rapid expansion of crack resulted in spalling after several repeated cycles.

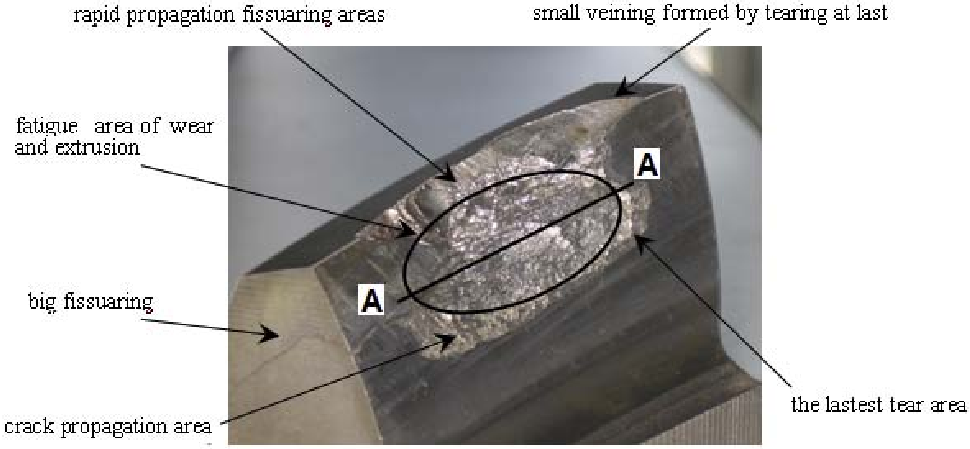

Fig.1. Fractured conical shaped gear and its fissuaring

3. Chemical composition and microstructure analysis

It was seen from element analysis that the sample compositions (wt%) were as follows: C 0.19, Si 0.18, Mn 0.50, P 0.009, S 0.008, Cr 1.62, Ni 1.64, Mo 0.32. The contents of P and S were very low, indicating the sample belongs to high-quality alloy steel.

Fig.2. Metallographic (carburized layer) structure of the surface layer (×200)

Metallographic structure analysis was carried out for the samples from the adjacent spalling area. Coarse acicular martensite was found at the surface of gear tooth (carburized layer) (figure 2). The core structure was lath martensite (figure 3). Compared with the conventional heat treated structure of similar gear, the metallographic structure of the gear tooth with surface spalling was normal. However, laths and needles of martensite were obviously coarse. The original grain boundary could be clearly observed at the lath martensite zone, which suggested that the heating temperature of gear quenching was too high.

Fig.3. Metallographic structure(interior) of the gear tooth (×500)

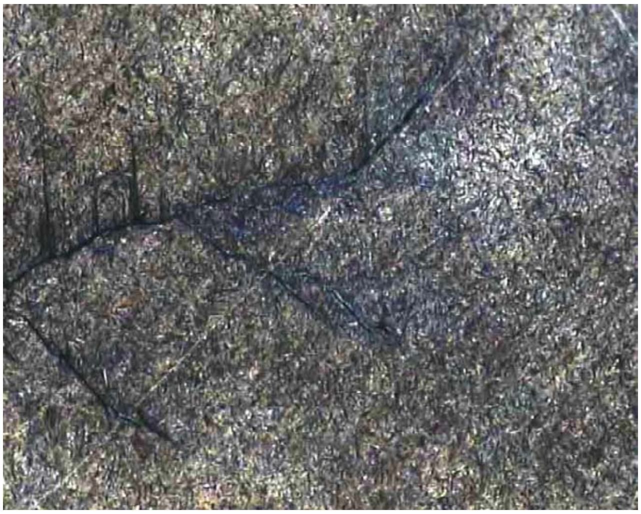

Fig.4. Small cracks (secondary cracks) on the gear tooth surface layer (×100)

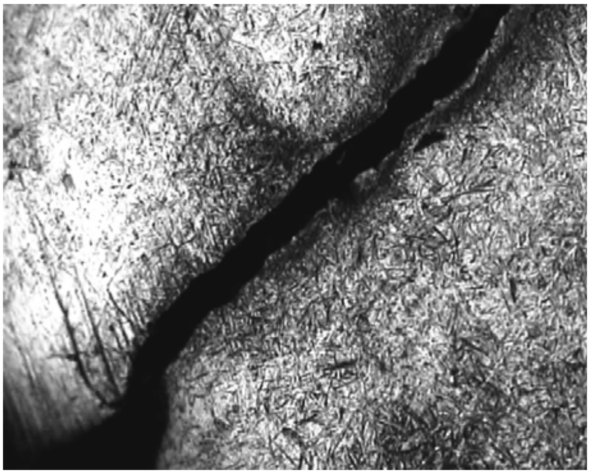

Fig.5. Acicular martensite at both sides of crack on the surface layer (×100)

Fig.6. Metallographic structure on one side of big crack (core)(×200)

Besides the large crack, as shown in figure 1, it was found that there were small cracks (secondary cracks) around the surface of gear tooth, as shown in figure 4. After analysis, at both sides of the crack on the surface layer (carburized layer) were coarse acicular martensite. The structure morpholog, shown in figure 5, was the same as surface layer in figure 2. The metallographic structure at both sides of large cracks near the core was lath martensite. Structure morphology was the same as that in the core of gear tooth in figure 3, which was shown in figure 6.

4. Hardness test

(1) The surface layer hardness values and core hardness values of gear surface were HRC59.3 and HRC 39.6, respectively, with loading force of 750 kg and loading time of 15s.

(2) Microhardness values at both sides of the near surface layer were Hv200 820 at the edge of crack, Hv200 980 at the range within 200 m far from the crack, Hv200 773 at the other places, respectively, with loading force of 200kg and loading time of 15s (figure 5).

5. Fracture morphology analysis

Fracture morphology was analysis by SEM electron microscopy, as shown in figure 7. It could be seen that the fracture had river-like pattern with cleavage fracture characteristics, mostly were transgranular fracture. It could be observed by electron microscopy that spalling face formed plastic deformation due to the two cracking faces squeezed with each other. Cracked grain faces had been planished during the cracking process, which indicated that the cracking faces had experienced the extrusion and wearing for a longer time.

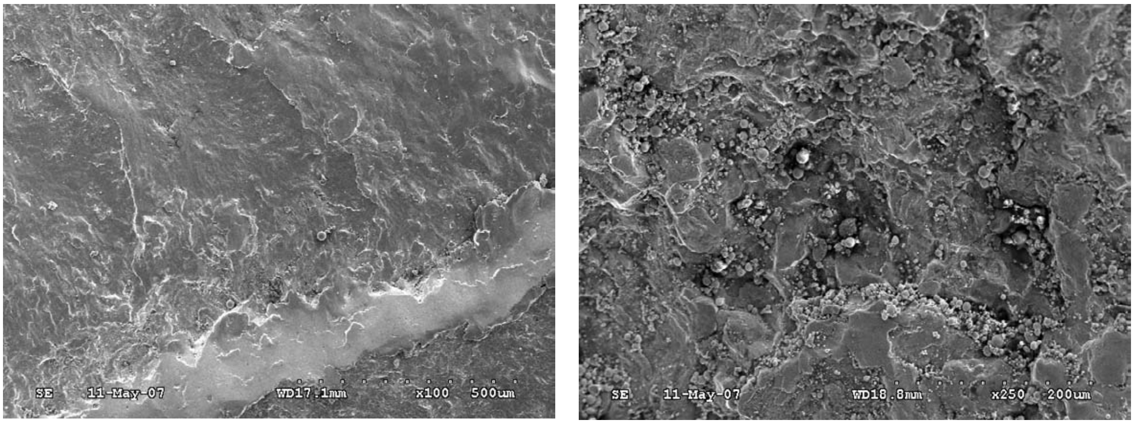

Fig.7. SEM photograph of fracture

6. Spalling process analysis of the gear tooth surface

From the above analysis, we conclude: (a) the composition of gear material could meet the requirements, evidenced by the very low content of S and P, and no obvious inclusions; (b) the material's morphology is near normal after heat treatment, but structure is relatively coarse; (c) there is internal crack exists inside the gear.

The cracking process could be identified as follows: small cracks in the gear tooth expanded during quenching and macro-cracks formed thereafter. Microstructure observation on the both sides of the cracks showed that the cracks on both sides neither obvious carburization nor clear decarburization phenomenon, which indicated that the crack has not extended to the tooth surface during the quenching. Once the cracks extend to the outer surface under the carburizing atmosphere, it would cause carburization on both sides of the cracks, and the heating during the quenching could lead to the significant decarbonization.

During the running of the gear, the surface suffered from alternating contact stress and bending stress. The stress in the crack tip could form a higher stress concentration, which induced the crack to expand further.

When the crack expanded to the carburizing layer which has very high hardness, the stress was parallel to the tooth surface and almost vertical to the crack at the transition part, i.e. area with the biggest contact stress. Hence, the crack changed the expansion direction and expanded along the transition interface between carburized layer and the matrix, as shown in figure 1. Two cracking faces crushed continuously, which could cause compressive fatigue, so the cracks continued expanding and the crack propagation took place when it expanded to a certain size until the surface peeled off bulk. The process of cracking spalling on the gear tooth was shown in figure 8.

Two points should be noted. Firstly, the gear tooth surface was peeling off due to the cracks. From material's shape and hardness after heat treated, as well as the surface state of other parts of the gear, it could be determined that the contact fracture phenomenon could not happen on the gear, and the fracture parts were not at the largest acting plane of the bending stress. Secondly, spalling faces extrusion and wear phenomenon were formed during the cracks expanding along the transition interface of carburized layer and the matrix. There was no possibility of friction after spalling.

Fig.8. Schematic representation for crack propagation, diversion and spalling

7. Conclusions

(1) Steel material composition of the gear meets the requirements. The content of S and P is very low, which belongs to high-quality alloy steel.

(2) The main reason for gear fracture spalling is the cracks inside the gear. The cracks expand under alternating stress until surface layer peels off. The formation and expansion of cracks is relevant to the manufacture process.

References

[1] Li Ying,ZHang Li-xin.Failure,Analysis on Teeth Break of Bevel Gear in Some Special Vehicle, Heat Treatment of Metals,s1,91-93(2007)

[2] ZHang Cun-xin, CHen Yu-ru,Analysis Method of Metallic Material Fracture,Physical Testing and Chemical Analysis Part A:Physical Testing, No. 11 622-625 (2008).

[3] You Zhao-hong,Fracture Analysis of Gears of a Speed Reducer,Materials for Mechanical Engineering,No.12 82-84(2008)

[4] Cao Guan-ghui,ZHao Cheng,Failure Analysis of Gear Transmission Shaft with Larger Diameter,Hot Working Technology , No.19 132-134 (2008).